The influence of environmental factors on distance/depth perception along underground pathways

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Introduction

Newly built subway lines in the middle of Tokyo run very deep in the ground since they need to be constructed beneath already existing subway lines. Passengers must therefore travel a long distance from the ground level to the platform. While traveling long distances through underground paths, the passengers may suffer from stress caused by feelings of claustrophobia and concerns for safety. Any knowledge regarding design features of underground pathways which might influence subjective distance and depth perception should be useful in devising measures to alleviate passengers' stress.

Most previous studies concerning distance perception have dealt with outdoor spaces (e.g., Nasar et al., 1985; Okabe et al., 1986; Katayama et al., 2001). Some have studied indoor distance perception (Sadalla et al., 1980; Hanyu et al., 1995; Ohno et al., 2001), but have rarely discussed depth perception. The present study therefore examines potentially influential environmental factors on both distance and depth perception through a series of experiments conducted along underground paths located near subway stations.

Method

Subjects

Twenty-seven (16 male and 11 female) university students were employed as subjects. They were divided into 8 groups each consisting of 3 or 4 people.

Experimental settings

Seven experimental sessions, each designed to compare different design features, were conducted using 12 paths around 3 subway stations in the middle of Tokyo (see Figure 1). Table 1 gives the physical characteristics of the paths including width, ceiling height, luminance and number of turns. This data was either measured on site or taken from architectural drawings.

Procedure

Each subject group, accompanied by an experimenter, was asked to walk along two underground paths that had different environmental features. Subjects were asked to estimate the length (traveling distance) and depth of the second path in relation to the first one through the Magnitude Estimation (M.E.) Method, in which a subject assigns a number to the second path in comparison with the first one, given a value of 100. At the same time, the subjects were also asked to rate their impressions of the overall atmosphere of the spaces surrounding each path using the five bipolar adjective pairs shown in Table 2. To account for possible order effects, half of the subject groups walked the two paths with the order reversed.

Results and discussion

Calculation of the extension ratio

In order to obtain a numerical index to assess the influences, the extension ratio (ER) was defined by the following equation.

$$ER(a,b)=1/100 \cdot ME(a,b) \cdot La/Lb$$

Where ER(a,b): the extension ratio of path (b) against path (a)
ME(a,b): number assigned to path (b)
La: physical length (or depth) of path (a)
Lb: physical length (or depth) of path (b)

Since no significant order effects were detected, the data obtained from the subject group who compared paths in the reverse order was treated by calculating the reciprocal value of the ER. The average ERs of the distance and depth estimations given by the subjects are shown in Table 3.

Influential environmental factors

The influence exerted on distance/depth perception by each physical feature will be discussed by analyzing the results of the experiment shown in Table 3 against the physical characteristics listed in Table 1.

< Path width >

The results of experimental sessions 1 and 6 reveal that wider paths (B-s and H-e) were perceived to be shorter and less deep.

< Spaciousness (void spaces with high ceilings and good visibility) >

In session 4 path C-e, which runs through a void space (a space with high ceilings and good visibility), was underestimated in both length and depth.

Session 2 was also designed to test the effects of void space. Path C-s, which contained a large void space was however perceived to be longer than path D-s, consisting of a narrow long corridor. This may have been caused by differences in speed of travel: path D-s requires relatively shorter time and thus may have been perceived as being of shorter distance. The depth of path C-s was underestimated as expected.

＜Settings with Stairways>

Path A-s
narrow, dark

Path B-s
wide, bright

Path C-s
void space, bright

Path D-s
a tunnel like path

Path E-s
two turns

Path F-s
no turn

＜Setting with Escalators>

Path C-e
void space, bright

Path F-e
no turn, dark

Path G-e
no turn, bright

Path H-e
large open space

Path I-e
narrow

Path J-e
one turn

Figure 1 Experimental settings

Table 1. Physical characteristics of the 12 paths used in the experiment

Session		Session 1 (S−1)		Session 2 (S−2)		Session 3 (S−3)		Session 4 (E−4)		Session 5 (E−5)		Session 6 (E−6)		Session 7 (E−7)	
paths compared		A−s	B−s	C−s	D−s	E−s	F−s	C−e	F−e	F−e	G−e	H−e	I−e	J−e	H−e
length (m)		17.6	32.9	40.0	65.8	30.9	33.7	39.8	34.1	34.1	29.5	78.3	72.3	60.4	78.3
depth (m)		6.7	10.5	12.4	10.6	10.2	9.4	12.4	9.4	9.4	11.3	26.7	24.5	26.7	26.7
calling height	max (m)	5.25	5.7	17.4	6.05	2.8	3.5	17.4	3.5	3.5	5.1	8.4	8.2	8	8.4
	min (m)	2.34	2.5	5.2	2.25	2.5	2	5.2	2	2	2.5	2.5	2.5	2.5	2.5
width	max (m)	3	4.6	13.0	4.45	3.4	3.8	13.0	3.8	3.8	4.6	12.5	9.1	12.5	12.5
	min (m)	2	3.15	2.45	2.00	1.5	2	2.45	2	2	4.2	3.37	0.9	3.37	3.37
number of turns		0	0	1	1	2	0	1	0	0	1	0	0	1	0
visible depth (m)		19.4	33.7	24.2	16	16.9	17.4	24.2	17.4	17.4	18	35.7	27.7	28.8	35.7
luminance (lx)	max	4000	1800	5950	7600	5350	255	5950	255	255	4400	630	700	630	630
	min	105	240	400	190	85	140	400	140	140	40	100	101	70	100
	mean	319	417	2243	901	669	187	2243	187	187	1439	281	346	263	281
	S.D.	954	313	1888	1676	1079	25	1888	25	25	1618	109	139	118	109
average slant angle		3.63	2.66	2.12	0.53	2.24	1.77	2.73	1.68	1.68	4.64	2.68	3.06	11.1	2.68

*Data given in white letters with black background indicates marked differences between the physical features of the two paths paired for each session, characteristics which were expected to most influence distance/depth perception.

Table 2. Five adjective pairs for rating space impressions

closed	+−−+−−+−−+−−+−−+−−+−−+−−+−−+−−+	open
dark	+−−+−−+−−+−−+−−+−−+−−+−−+−−+−−+	bright
dirty	+−−+−−+−−+−−+−−+−−+−−+−−+−−+−−+	clean
unsafe	+−−+−−+−−+−−+−−+−−+−−+−−+−−+−−+	safe
tiring	+−−+−−+−−+−−+−−+−−+−−+−−+−−+−−+	not tiring
	−5 −4 −3 −2 −1 0 1 2 3 4 5	

Table 3. Experimental results: average extension ratios and impression ratings

Session		Session 1 (S−1)		Session 2 (S−2)		Session 3 (S−3)		Session 4 (E−4)		Session 5 (E−5)		Session 6 (E−6)		Session 7 (E−7)	
paths compared		A−s	B−s	C−s	D−s	E−s	F−s	C−e	F−e	F−e	G−e	H−e	I−e	J−e	H−e
avg. required time (sec)		27	40	47	63	38.8	38.6	66.1	56.9	56.9	59.7	127	115	127	127
avg. time per meter (sec)		1.53	1.22	1.18	0.96	1.26	1.15	1.66	1.67	1.67	2.02	1.63	1.59	2.11	1.63
length	M.E. value	−	114	−	119	−	100	−	96.2	96.2	110	109	101	−	109
	ext. ratio	−	0.61	−	0.67	−	0.92	−	1.16	−	1.27	−	1.09	−	0.84
depth	M.E. value	−	107.0	−	101.2	−	96.7	−	96.7	−	107.8	−	99.7	−	104
	ext. ratio	−	0.68	−	1.19	−	0.994	−	1.28	−	0.90	−	1.09	−	1.04
impression	openness	−2	0.4	3.54	−2	−2.7	0.08	3.5	−1.8	−1.8	2.6	0.13	−0.9	−0	0.13
	brightness	−2.4	0.3	3.46	−1.3	−1.1	0.25	2.96	−1.5	−1.5	2.3	0.83	0.71	0.83	0.83
	cleanliness	−2.3	−0.3	3.54	−1.2	−1.2	−0.5	3.63	−2	−2	3.3	1.5	1.71	1.67	1.5
	safety	−2.1	0.3	2.42	−1.3	−1.6	0.17	2.33	−1.3	−1.3	2.3	−0.2	−0.6	−0.3	−0.2
	tiring/not	−0.8	−0.8	0.13	−1.6	−1.8	−0.5	2.58	−0	−0	2.8	0.38	−0.1	0.46	0.38

*Data given in white letters with black background indicates a statistically significant difference (5%)
*Data given in bold letters with gray background indicates a relatively large difference (2>) between impressions of the two paths.

< Existence of turns >

In session 3, path E-s, consisting of two turns, was perceived to be longer than path F-s which had no turns. Session 7 also revealed that path J-e, which has one turn between two escalators, was perceived to be longer than path H-e, which has a single straight escalator.

Unexpected results were obtained for session 5, which had been intended to test the effect of brightness. Path G-e, though far brighter than path F-e, was perceived to be longer. This may have been due to the existence of a turn in path G-e. It seems that the effect imposed by turns is stronger than that brought on by brightness.

However, the results obtained for session 4was inconsistent with the above explanation. Here, path C-e with one turn was perceived to be shorter than path F-e, which had no turns. Considering the fact that path C-e goes through a large void space (an atrium), it may be that the subjects continue to feel as if they are moving within a single continuous space even after the change of direction, thus leading the abovementioned effect of spaciousness to prevail over the effect of turns.

<u>Relationship between impressions of a space and distance/depth perception</u>

Subjects' ratings of their impressions of each space are shown at the bottom of Table 3. As shown in Table 4, high correlation coefficients were derived between the psychological scales of openness, brightness, cleanliness, and safety. In sessions 1 and 4, paths that rated positively in these aspects were perceived to be shorter. Although sessions 2 and 5 showed incongruent results due to the reasons already discussed above, it may generally be concluded that positively evaluated spaces are perceived to be shorter.

Table 4. Correlation coefficients between the psychological scales used in rating impressions of the underground path spaces

	openness	brightness	cleanliness	safety
tiring/not	-0.66	-0.61	-0.64	0.61
safety	-0.82	-0.78	-0.8	
cleanliness	0.85	0.85		
brightness	0.9			

Conclusion

The results of the experiment generally support the hypothesis that certain pathway design features will influence distance/depth perception. The experiment revealed that wider and more open paths tended to be judged shorter and set less deep underground. It was found that paths with more turns were judged longer though this effect was not found for paths running through an atrium. As for the effect of the overall atmosphere along the path, spaces that provided impressions of brightness, openness, cleanliness and safety made subjects judge the paths to be shorter and less deep.

References

Hanyu, K. and Itsukushima, Y.: Cognitive distance of stairways, Distance, traversal time, and mental walking time estimates, *Environment and Behavior,* vol.27, no.4, pp.579-591, 1995

Katayama, M. and Ohno, R.: A Study of Pedestrian's Cognitive Distance of a Commuting Route, *Journal of Archit. Plann. Environ. Eng.*, AIJ, no. 549, pp. 193-198, Nov., 2001

Nasar, J.L., Valencia, H., Omar, Z.A., Chueh, S. and Hwang,J.: Out of Sight Further from Mind, Destination visibility and distance perception, *Environment and Behavior*, vol.17, no.5, pp.627-639, 1985

Ohno, R., Katayama, M., Komatsuzaki, T. and Soeda, M.: A Study of Pedestrian's Cognitive Distance of a Commuting Route, *Journal of Archit. Plann. Environ. Eng., AIJ*, no. 550, pp. 95-100, Dec., 2001

Okabe, A., Aoki, K., and Hamamoto, W.: Distance and Direction Judgment in a Large-Scale Natural Environment, Effects of a slope and winding trail, *Environment and Behavior,* vol.18, no.6, pp.755-772, 1986

Sadalla, E. K. and Staplin, L. J.: The Perception of Traversed Distance, *Environment and Behavior*, vol.12, no.1, pp.65-79, 1980

Summary

The present study examines the influence of environmental factors on distance/depth perception through a series of experiments conducted along underground paths located near subway stations. Subjects (16 male and 11 female university students) were divided into 8 groups each consisting of 3 or 4 people. Each subject group, accompanied by an experimenter, was asked to walk along two underground paths that had different environmental features. Each subject was asked to estimate the ratio of the length of the second path to the first one. At the same time, they were also asked to rate the overall atmosphere of the path. Seven such experimental sessions were conducted using 12 paths around 3 subway stations in the middle of Tokyo. Physical characteristics of the paths such as width, ceiling height, luminance and number of turns were either measured on site or taken from architectural drawings. The results of the experiment generally support the hypothesis that certain pathway design features will influence distance/depth perception. The experiment revealed that wider and more open paths tended to be judged shorter and set less deep underground. It was also found that paths with more turns were judged longer, though this effect was not found for paths running through an atrium. As for the effect of the overall atmosphere along the path, spaces that provided impressions of brightness, openness, cleanliness and safety made subjects judge the paths to be shorter and less deep.